# Ch. 2 OSCILLATORS


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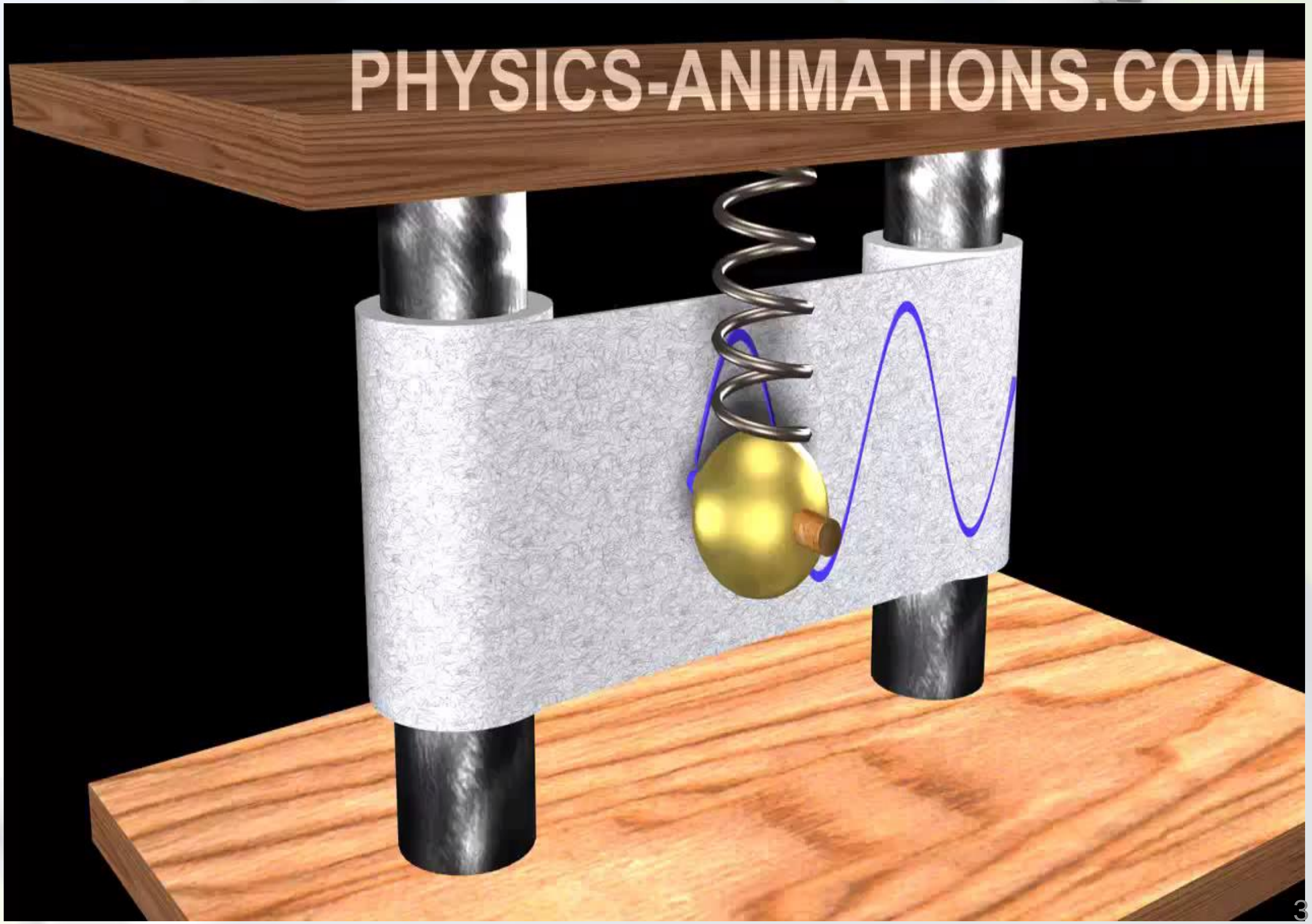
# 1- What is Oscillator?

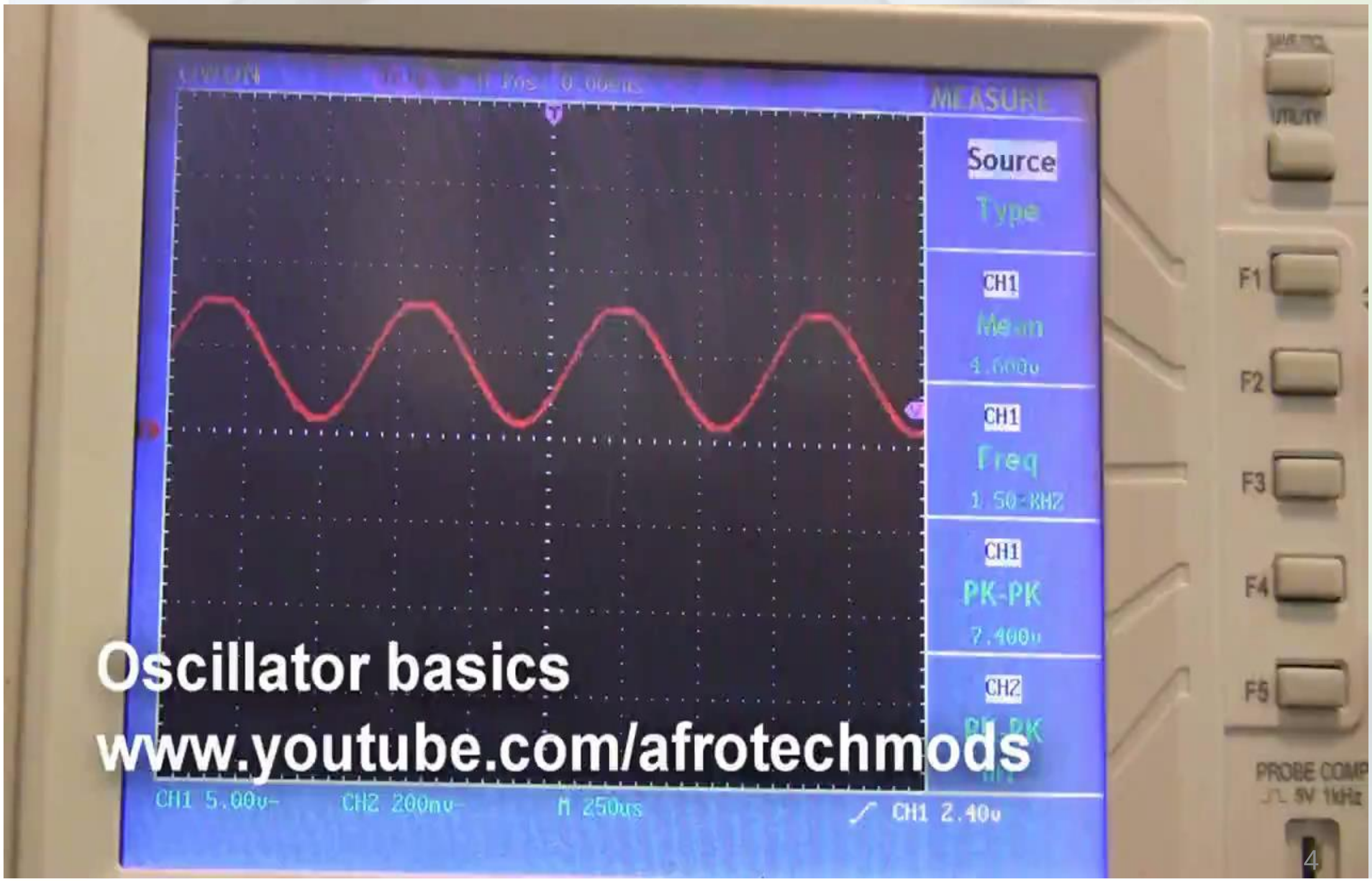


- **An electronic oscillator is an electronic circuit that produces a repetitive, oscillating electronic signal, often a sine wave or a square wave. Oscillators convert direct current (DC) from a power supply to an alternating current signal.**

# 1- What is Oscillator?



# 1- What is Oscillator?



# Alternator vs Oscillator



- For several applications, especially for low power requirements. …… Why?
  - Can generate AC voltages at any frequency adjustable over a wide range of frequency.
  - It is possible to generate harmonic free sinusoidal signals.
  - In oscillators, the frequency remains constant with time.

# Applications



- **Oscillators are used for various purposes such as in radio transmitters and receivers, in television transmitters and receivers, in radar, for measurement purposes and for high frequency heating.**
- **Signals of other waveforms, such as pulse, square, saw tooth etc. are also generated for their specific uses. The oscillators made for generating these waveforms are given special names. We shall discuss various types of oscillators in later sections.**

# Features

- An audio oscillator produces frequencies in the audio range, about 16 Hz to 20 kHz.
- An RF oscillator produces signals in the radio frequency (RF) range of about 100 kHz to 100 GHz.
- A low-frequency oscillator (LFO) is an electronic oscillator that generates a frequency below ≈20 Hz. This term is typically used in the field of audio synthesizers, to distinguish it from an audio frequency oscillator.

# Practical oscillator


**Figure 2.1:** 1 MHz electronic oscillator circuit which uses the vibrations of an internal quartz crystal to control the frequency. It provides the clock signal for digital devices such as computers.

# The basic principle of oscillators

forward and feedback path transfer functions

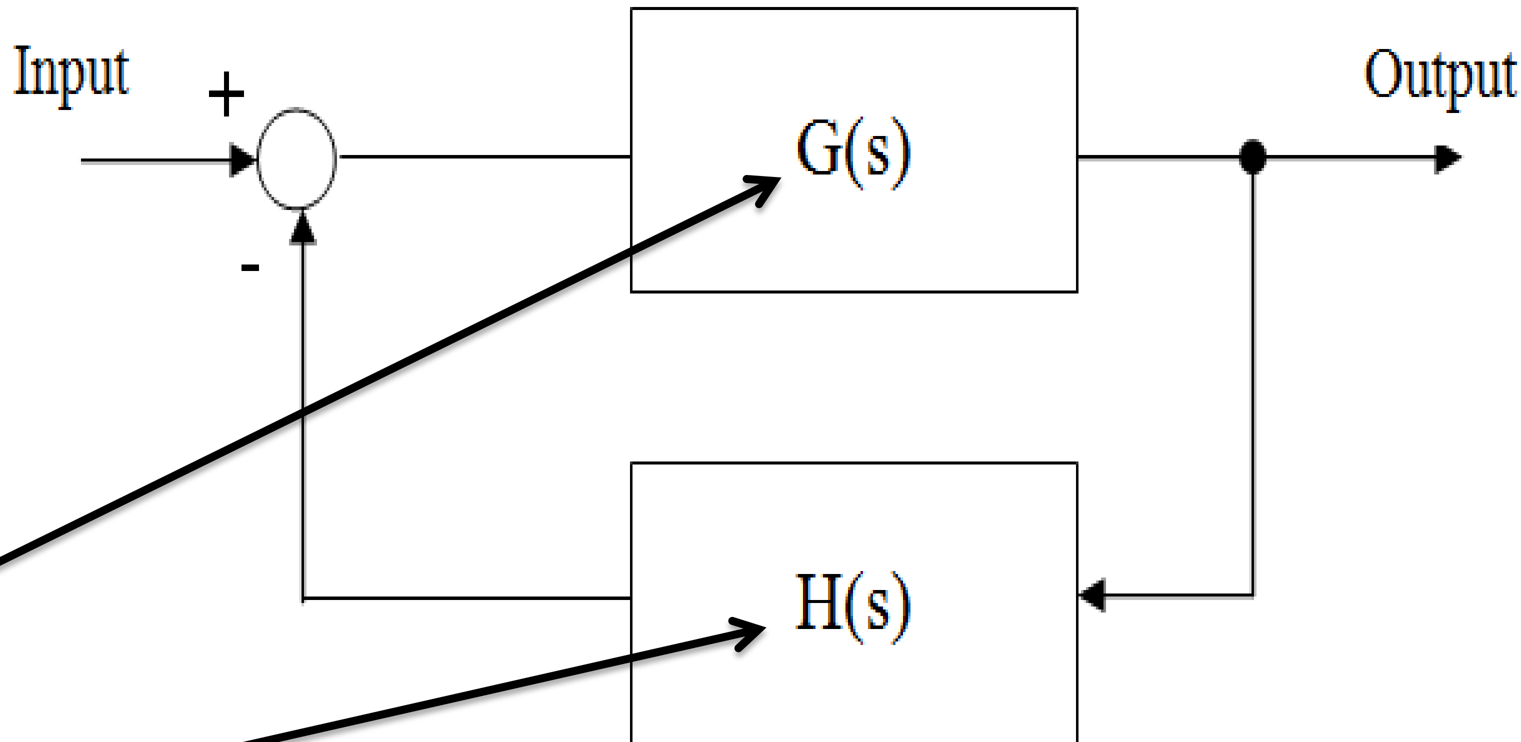



Figure 2.2: Block diagram of oscillators

# The close loop transfer function of the system is given by

$$\frac{C(s)}{R(s)} = \frac{G(s)}{1 - G(s)\,H(s)}$$

**The feedback loop can be adjusted such that at a particular frequency:**

$$|\,G(s)\,H(s)\,| = 1$$

**This means that the gain of the close loop system is infinite, i.e., theoretically even with input zero there will be an output at that particular frequency. So, the system behaves as an oscillator giving an output without an input.**

# What is meant by

**The frequency of oscillation of an oscillator?**

**Answer**

# Is that condition is practical??



$$|\,G(s)\,H(s)\,| = 1$$

**If the value becomes less than unity, the oscillation simply stops and when it is greater than unity, the amplitude of oscillation is limited by the onset of nonlinearity.**

**Thus, in a particular oscillator the adjustment is always made to have $|\,G(s)\;H(s)\,|$ somewhat greater (about 0.5 percent) than unity.**

# For self-sustaining oscillations:



1. the feedback signal must positive.
2. the overall gain must be equal to one (unity gain)

**If** the feedback signal is not positive or the gain is less than one, then the oscillations will dampen out.

**If** the overall gain is greater than one, then the oscillator will eventually saturate.

# Types of oscillators



1- Phase-shift oscillator.
2- Resonant circuit oscillator.
3- Wien bridge oscillator.
4- Crystal oscillator.

# Types of oscillators



1- **Phase-shift oscillator**

# Phase-shift oscillator

Is a linear electronic oscillator circuit that produces a sine wave output.

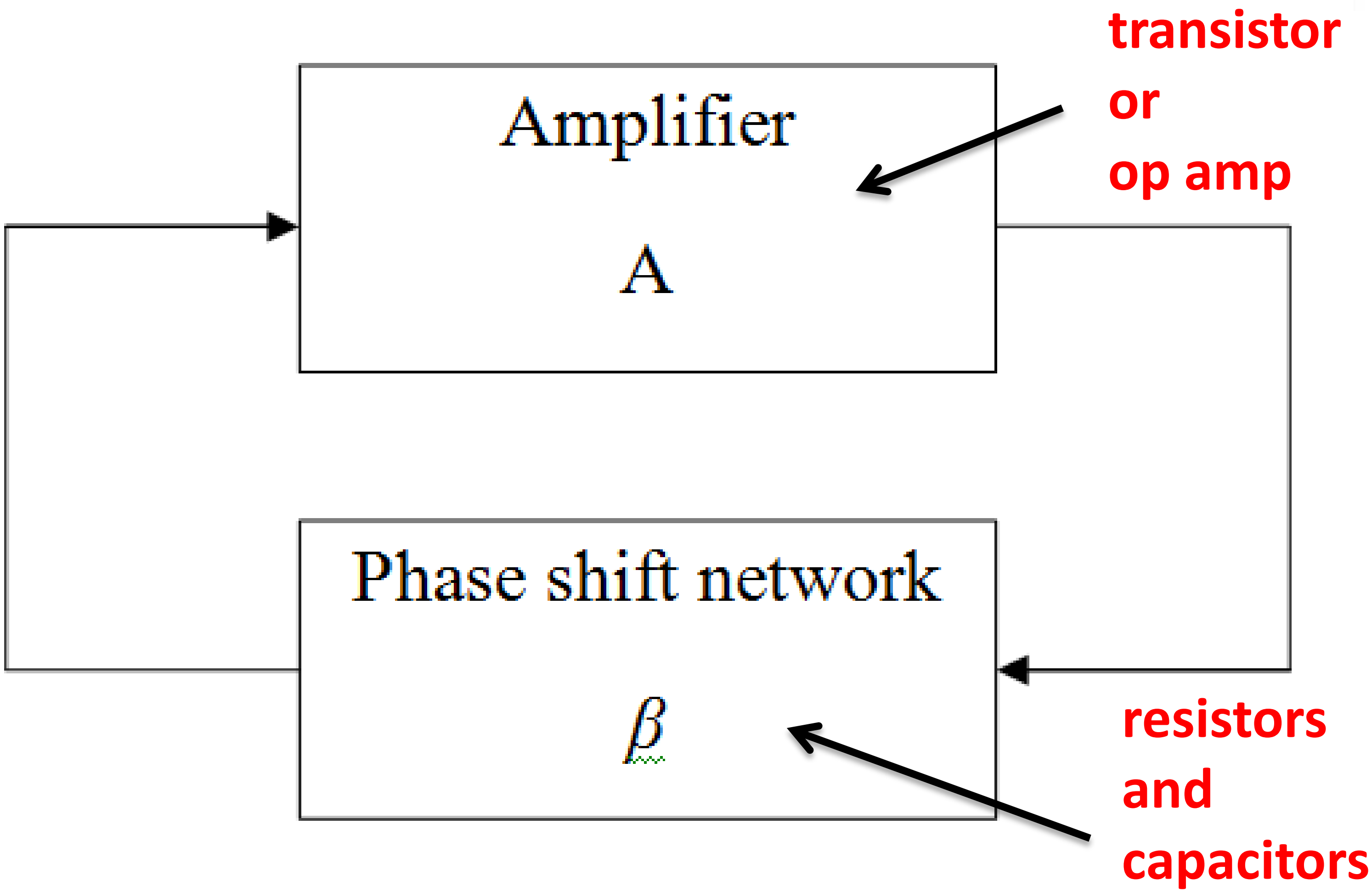



Figure 2.3: A phase shift oscillator

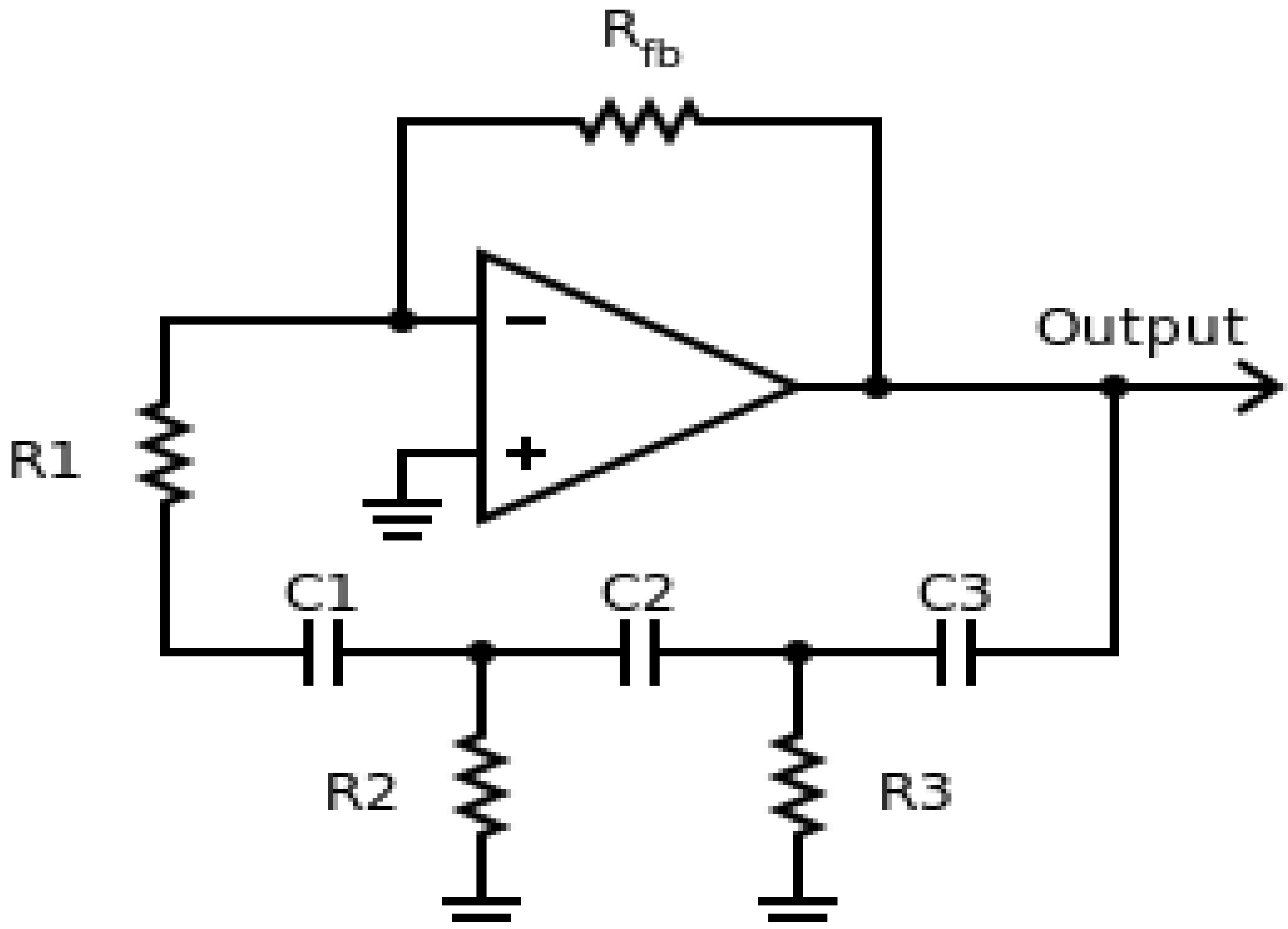
# Phase-shift oscillator

**The feedback network 'shifts' the phase of the amplifier output by 180 degrees at the oscillation frequency to give positive feedback.**

**At a particular frequency the phase-shift introduced by the network may be precisely 180 degrees and at this frequency the total phase shift in the loop becomes exactly zero. If $|A\beta|$ is set equal to unity, the following circuit will oscillate at this particular frequency.**

# Phase-shift oscillator

Op-amp implementation



# Phase-shift oscillator

Op-amp implementation

**For simplicity**

**$R_1 = R_2 = R_3 = R$, and**

**$C_1 = C_2 = C_3 = C$, then:**

$$f_{\text{oscillation}} = \frac{1}{2\pi RC\sqrt{6}}$$

**and the oscillation criterion is:**

$$R_{\text{fb}} = 29 \cdot R$$

# Phase-shift oscillator



**Op-amp implementation**

## Without the simplification

$$f_{\text{oscillation}} = \frac{1}{2\pi\sqrt{R_2R_3(C_1C_2 + C_1C_3 + C_2C_3) + R_1R_3(C_1C_2 + C_1C_3) + R_1R_2C_1C_2}}$$

## Oscillation criterion:

$$R_{\text{fb}} = 2(R_1 + R_2 + R_3) + \frac{2R_1R_3}{R_2} + \frac{C_2R_2 + C_2R_3 + C_3R_3}{C_1}$$
$$+\frac{2C_1R_1 + C_1R_2 + C_3R_3}{C_2} + \frac{2C_1R_1 + 2C_2R_1 + C_1R_2 + C_2R_2 + C_2R_3}{C_3}$$
$$+\frac{C_1R_1^2 + C_3R_1R_3}{C_2R_2} + \frac{C_2R_1R_3 + C_1R_1^2}{C_3R_2} + \frac{C_1R_1^2 + C_1R_1R_2 + C_2R_1R_2}{C_3R_3}$$

# Phase-shift oscillator



Op-amp implementation

In a purely ideal circuit, some sort of non-zero initial condition needs to be injected into the circuit in order to start the oscillation. In practice, the noise present (predominantly thermal noise from the resistors) is sufficient to provide an initial signal to start the oscillation.

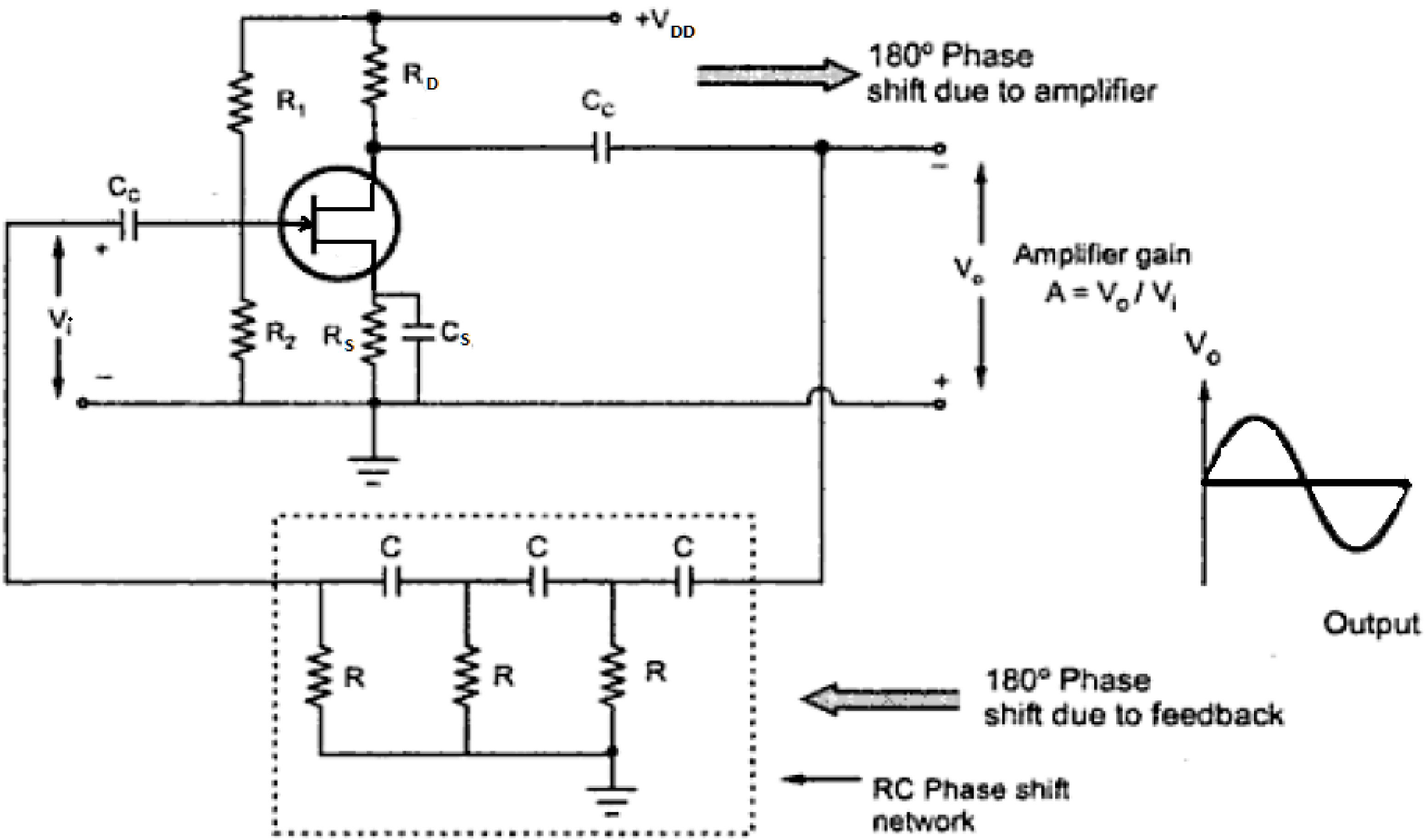
# Phase-shift oscillator

**Op-amp implementation**

**One potential problem with the single op-amp circuit is the high gain required to maintain the oscillation. If it is assumed that each RC segment does not affect the other, a gain of about 8 to 10 will be sufficient to enable oscillation. As mentioned previously, each RC section loads the next section, and a larger gain (about 27 to 30) is required to keep the circuit in oscillation. An improved version of this circuit can be made by putting an op-amp buffer between each RC stage. The voltage gain of the inverting channel is always unity.**

# Phase-shift oscillator

FET implementation



# Phase-shift oscillator



## FET implementation

**The feedback factor or parameter can be given by:**

$$-\beta = \frac{V_i}{V_o} = \frac{1}{1 - 5\alpha(6 - \alpha^2)}$$

**Where $\alpha = 1 / \omega CR$**

**For 180° phase-shift introduced by the network, $\alpha^2 = 6$ or:**

$$f = \frac{1}{2\sqrt{6}\,\pi CR}$$

# Phase-shift oscillator



FET implementation

1. At the frequency of oscillation, $\beta = 1/29$.
2. The amplifier must supply enough gain to compensate for losses. The overall gain must be unity. Thus the gain of the amplifier stage must be greater than $1/\beta$, i.e. $A > 29$.
3. The RC networks provide the necessary phase shift for a positive feedback. They also determine the frequency of oscillation.

# THANK YOU

**Dr Mohamed Salah**